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Collective induction is the cooperative search for descriptive, predictive, and explanatory generalizations, rules, and principles. This article proposes a theory of collective induction in the form of seven postulates. It then describes a rule induction task that abstracts the two essential aspects of collective induction, group hypothesis formation and group hypothesis evaluation. The theory predicts the conditional probabilities of 11 types of group hypotheses for 38 types of distributions of correct, plausible, and/or nonplausible group member hypotheses on trial _t_ (group hypothesis formation). These predictions fit the obtained probabilities for 400 groups better than the predictions of two other plausible theories, each with considerable support in previous research on group problem solving and decision making. Three other sets of predictions were also derived from the seven postulates and supported by the results. These were the transition probabilities from correct, plausible, and nonplausible group hypotheses on trial _t_ to correct, plausible, and nonplausible hypotheses on trial _t_+1; the order of the proportions of confirming and disconfirming responses for the five (OVER)

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19. (continued) possible types of relationships between the group hypothesis and the correct rule (group hypothesis evaluation); and the order of the conditional probabilities of a correct group hypothesis on trial *t*+1 given confirming and disconfirming responses for the five types of group hypotheses on trial *t*.

A Theory of Collective Induction

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23 January, 1989

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Abstract

Collective induction is the cooperative search for descriptive, predictive, and explanatory generalizations, rules, and principles. This article proposes a theory of collective induction in the form of seven postulates. It then describes a rule induction task that abstracts the two essential aspects of collective induction, group hypothesis formation and group hypothesis evaluation. The theory predicts the conditional probabilities of 11 types of group hypotheses for 38 types of distributions of correct, plausible, and/or nonplausible group member hypotheses on trial *t* (group hypothesis formation). These predictions fit the obtained probabilities for 400 groups better than the predictions of two other plausible theories, each with considerable support in previous research on group problem solving and decision making. Three other sets of predictions were also derived from the seven postulates and supported by the results. These were the transition probabilities from correct, plausible, and nonplausible group hypotheses on trial *t* to correct, plausible, and nonplausible hypotheses on trial *t*+1; the order of the proportions of confirming and disconfirming responses for the five possible types of relationships between the group hypothesis and the correct rule (group hypothesis evaluation); and the order of the conditional probabilities of a correct group hypothesis on trial *t*+1 given confirming and disconfirming responses for the five types of group hypotheses on trial *t*.

A Theory of Collective Induction

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Consider small groups of scientific researchers, weather forecasters, petroleum geologists, securities analysts, political prognosticators, market researchers, auditors, intelligence analysts, corporate board members, or air crash investigators. Although the objectives and task domains of these groups vary greatly, all of them engage in collective induction, the cooperative search for descriptive, predictive, and explanatory generalizations, rules, and principles. In the process of induction, all of these groups observe patterns, regularities, and relationships in some domain, propose hypotheses to account for them, and evaluate the hypotheses by observation or experiment. In the process of collective induction, all of these groups map a distribution of group member hypotheses onto a single group response by some social combination process.

This article proposes a theory of collective induction in the form of seven postulates. It then describes a rule induction task that abstracts the two essential processes of collective induction, hypothesis formation and hypothesis evaluation. Four sets of predictions are then derived from the theory and tested for 400 four-person groups on the rule induction task.

Seven Postulates

Table 1 gives the seven postulates of the theory.

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Insert Table 1 about here

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Postulate 1: Group problem solving and decision making is a social combination process that maps a distribution of individual group member preferences onto a single collective group response.

Postulate 1 is the fundamental assumption of a social combination approach to group problem solving and decision making. Current social combination approaches originate in the classic paper of Lorge and Solomon (1955), whose "Model A" applied the binomial theorem to predict the probability of group solution, P_G, given the probability of individual solution, P_I, and the assumption of random assignment of these individuals to groups of size k: $P_G = 1 - (1 - P_I)^k$. This formalizes the strong "truth wins" assumption that the group will recognize and adopt the correct answer if it is proposed by at least one individual group member.

Thomas and Fink (1961) extended this special case binomial theorem for two alternatives (correct and incorrect) to the general case multinomial theorem for three or more alternatives. They also tested three assumed social combination processes rather than just "truth wins." Smoke and Zajonc (1962) introduced the concept of group decision schemes as formalizations of the assumed social combination process. They also proposed several decision schemes, such as quorums of different sizes, including the "minimal quorum" of one or Lorge and Solomon Model A. Steiner (1966, 1972) predicted group productivity from assumptions of the optimal process on different types of tasks and his theory of motivation and coordination loss. Davis (1973) integrated the multinomial theorem of Thomas and Fink and the concept of group decision schemes as formalizations of the assumed group process of Smoke and Zajonc in a matrix algebra formulation in his theory of social decision schemes. Shiflett (1979) further generalized the social combination approach.

Three further developments of social combination approaches are extensions to social choice models, dynamic models, and integration with cognitive processes models by computer simulations. For example, Castore and Murnighnan (1978) and Crott, Zuber, and Schermer (1986) related social combination approaches to social choice models of collective preference orders (Black, 1958). Kerr (e.g., 1981, 1982; Kerr & MacCoun, 1985) extended a static social combination approach to a dynamic social combinaion approach in his theory of social transition schemes. Penrod and Hastie (1980) and Stasser (1988) integrated social combination and cognitive process models in computer simulations of group decision making. For further discussion of the general social combination approach see Davis (1973, 1980, 1982), Laughlin (1980), Laughlin and Adamopoulos (1982), and Stasser, Kerr, and Davis (*in press*).

Postulate 2: Group problem solving and decision making tasks may be ordered on a continuum anchored by intellective and judgmental tasks.

Postulate 2 was first proposed by Laughlin (1980). . Intellective tasks are problems or decisions for which there exists a demonstrably correct solution within a verbal or quantitative conceptual system. Examples include object transfer problems (e.g., Shaw, 1932), water jar or gold dust problems (e.g., Davis & Restle, 1963), anagrams (e.g., Faust, 1959), and most of the tasks in the group problem solving traditions summarized by Kelley & Thibaut (1969), Hackman and Morris (1975), Hastie (1986), Hill (1982), Lorge, Fox, Davitz, and Brenner (1958), and McGrath (1984). Intellective tasks emphasize the solution of a problem by a series of permissable operations within some set of constraints. Problem solution is defined by the relationships of the verbal or quantitative conceptual system within which the problem is defined and embedded. The objective for the group is to achieve the correct solution, and the criterion of group success is whether or not the solution is achieved.

Judgmental tasks are evaluative, behavioral, or aesthetic judgments for which a demonstrably correct response does not exist. Examples include virtually all of the tasks in research on the choice shift and group polarization (for reviews see Burnstein, 1982; Lamm & Myers, 1978; Myers, 1982), Myers & Lamm, 1976), mock jury decisions (for reviews see Davis, 1980; Hastie, Penrod, and Pennington, 1984; Penrod & Hastie, 1979), and evaluative attitudinal judgments. On judgmental tasks the objective for the group is to achieve consensus, and the criterion of group success is whether or not consensus is achieved. For example, a jury that fails to reach consensus or "hangs" has failed to achieve the objective of a jury trial.

In summary, Postulate 2 proposes that intellective and judgmental tasks are the endpoints of a continuum rather than a dichotomy. For further discussion of this continuum of group tasks and relationships to other task taxonomies see Laughlin (1980), McGrath (1984), and Kaplan and Miller (1987).

Postulate 3: A demonstrably correct group response requires four conditions:

Postulate 3a: There must be group consensus on a verbal or quantitative conceptual system.

Postulate 3b: There must be sufficient information for solution within the system.

Postulate 3c: The group members who are not themselves able to achieve the correct response must have sufficient knowledge of the system to recognize and accept a correct response if it is proposed by other group members.

Postulate 3d: The correct members must have sufficient ability, motivation, and time to demonstrate the correct response to the incorrect members.

Postulate 3 was first proposed by Laughlin and Ellis (1986). Postulate 3a indicates that demonstrability presupposes previous group consensus on a conceptual system. A verbal conceptual system such as a language or constitution assumes consensus on the vocabulary, syntax, and relationships of the system. A mathematical system such as geometry or algebra assumes consensus on the primitive terms, axioms, and operations of the system. Given this consensus on the system, Postulate 3b indicates that there must be sufficient information for solution. For example, a system of two simultaneous equations in two unknowns has a unique solution, but one equation in two unknowns does not. Postulate 3c indicates that the group members who do not know the correct response must be able to recognize it if it is proposed by the members who do. This was an implicit assumption for the Lorge and Solomon (1955) Model A. Postulate 3d specifies the characteristics of the group members who know the correct response that are necessary for them to demonstrate it to the members who do not know it.

Postulate 4: The number of group members that is necessary and sufficient for a group response is inversely proportional to the demonstrability of the response.

Postulate 4 was first proposed by Laughlin and Ellis (1986) as a generalization from their review of the best-fitting social combination processes on five sets of group tasks.

Two-thirds majority, in which the group decision is that favored by two thirds of the group members, is the best-fitting social combination process for mock jury decisions of both size 12 and size 6. Juries without a two-thirds majority typically are either unable to come to a decision ("hang") or give the defendant the benefit of the doubt and acquit (e.g., Davis, Kerr, Atkin, Holt, & Meek, 1975; Davis, Kerr, Stasser, Meek, & Holt, 1977; Hastie, Penrod, & Pennington, 1984; Kerr et al, 1976; MacCoun & Kerr, 1988). Jury decisions are judgmental tasks because conviction or acquital is typically a matter of the more credible and persuasive scenario rather than a demonstrably correct response (Hastie, Penrod, & Pennington, 1984).

Simple majority, in which the group decision is that favored by more than half of the group members, is the best-fitting social combination process for attitudinal judgments and preferences among bets, especially when the majority position is in the direction of prevailing values or norms (e.g., Cvetkovich & Baumgardner, 1973; Davis, Kerr, Sussmann, & Rissman, 1974; Kerr, Davis, Meek, & Rissman, 1975; Lambert, 1976; Zaleska, 1976, 1978). Attitudinal judgments and preferences among bets are judgmental tasks because they are based on values rather than demonstrably correct answers.

Most of this research with jury decisions, attitudinal judgments, and preferences among bets has involved two response alternatives, such as conviction or acquital. An important exception is the four verdict categories, first-degree murder, second-degree murder, manslaughter, and not guilty, of Hastie, Penrod, and Pennington (1984). Although a majority social combination process fit very well for decisions of guilty (collapsing over the first three verdict categories) versus not guilty, a plurality process fit quite well when there was no majority. This suggests a general majority, plurality otherwise, social combination process for tasks with nondemonstrable answers and more than two response categories.

Equiprobability, in which the group response is equiprobable among all responses advocated by at least one group member, is the best-fitting social combination process on relatively uninvolving decisions, such as which of a set of lights will occur on a series of trials (e.g., Davis, Hornik, & Hornseth, 1970; Zajonc, Wolosin, Wolosin, & Sherman, 1968). Such tasks do not have demonstrablhy correct answers, and probably do not engage strong values. The best-fitting equiprobability social combination process may thus represent an attenuation of a more general majority process on more involving judgmental tasks that do engage strong values.

Truth-supported wins, in which two correct members are necessary and sufficient for a correct group response, is the best-fitting social combination process on general world knowledge, vocabulary, and analogy items (Laughlin & Adamopoulos, 1980, 1982; Laughlin, Kerr, Davis, Halff, & Marciniak, 1975; Laughlin, Kerr, Munch, & Haggarty, 1976). These tasks fit the four conditions of demonstrability of Postulate 3, but the correct answers are not intuitively obvious or immediately evident once proposed. On these tasks a correct member must be supported by another correct member to persuade the remaining incorrect members to adopt the correct answer as the group response.

Bottger and Yetton (1988) used the "Moon Survival" problem to assess their theory of expert weighting, which is related to the optimal weighting approach of Einhorn, Hogarth, and Klempner (1977). In the Moon Survival problem one imagines oneself an astronaut who has crash landed on the moon

200 miles from base. Fifteen items of equipment (tank of oxygen, rope, etc.) are ranked in order of contribution to survival on a walk to the base. The criterion of task success is correspondence to the previous rank order of the Crew Equipment Research Unit of NASA. Subjects ranked the items alone and then in groups of size four, five, or six. Group performance was successfully predicted by the ability of the two most expert group members, corresponding to a truth-supported wins social combination process.

Truth-wins, in which one correct member is necessary and sufficient for a correct group response, is the best-fitting social combination process on insight or "Eureka" puzzles (Shaw, 1932; Marquart, 1955), creativity tasks (Laughlin, Kerr, Munch, & Haggarty, 1976), and mathematical problems (Laughlin & Ellis, 1986). These tasks fit Postulates 3a and 3b, and have correct answers that are either intuitively and immediately obvious or demonstrable to incorrect members (Postulate 3c) by a single (unsupported) correct member (Postulate 3d). On these tasks a single correct member suffices to persuade the incorrect members to adopt the correct answer as the group response.

Correct answers on complex tasks such as the "Moon Survival" problem (Bottger & Yetton, 1988; Yetton & Bottger, 1983), "island" problem (Tuckman, 1967), or "mined road" problem (Tuckman & Lorge, 1962) are directly defined by correspondence to the answers of an external group of experts and only indirectly defined by demonstration within a conceptual system. Such tasks are intermediate on the continuum of Postulate 2 between intellective tasks on which correct answers are defined by demonstration within a conceptual system and judgmental tasks on which no correct answers exist and the criterion of success is the consensus of the group members themselves, whatever their expertise, such as in juries.

In summary, previous research on social combination processes on a wide range of group tasks supports the generalization of Postulate 4 that the number of group members that is necessary and sufficient for a group response is inversely proportional to the demonstrability of the response. The conditions of demonstrability are specified by Postulate 3. Tasks at the intellective end of the continuum of Postulate 2 require the fewest members for a (correct) group response, and tasks at the judgmental end of the continuum require the most members for a (consensual) group response.

Postulate 5: If at least two members propose the same hypothesis the group selects among only those hypotheses proposed by the group members; if no two members propose the same hypothesis the group selects among the hypotheses proposed by the group members and proposes a new emergent group hypothesis with probability 1/S (where S is group size).

Postulate 5 states the assumption that groups typically select among the hypotheses proposed by the group members rather than generate new emergent group hypotheses. The results of two extensively researched areas support this assumption. First, research on brainstorming demonstrates that interacting groups produce fewer new ideas than an equivalent number of noninteracting individuals credited with nonredundant individual responses (nominal groups). See Diehl & Strobe (1987) for references and a review of 22 experiments. Second, research on social facilitation demonstrates that the presence of others serves to actuate dominant responses. See Bond & Titus (1983) for refrerences and a meta-analysis of 241 experiments). Postulate 5 assumes that new emergent group hypotheses will occur only if all members propose different hypotheses. In this case the probability of a new emergent group hypothesis is inversely proportional to the group size, reflecting the increasing difficulty of getting the group members to agree on a hypothesis none of them have proposed as group size increases.

Postulate 6: If at least two members propose plausible and/or correct hypotheses the group selects among proposed plausible and/or correct hypotheses only; if one or no members propose a plausible or correct hypothesis the group selects among all proposed hypotheses.

Proposed hypotheses are based on evidence. Postulate 6 assumes that this demonstration requires two plausible and/or correct members, in accord with the research reviewed under Postulate 4 in which a truth-supported wins social combination process has applied for responses that are demonstrably correct but not intuitively or immediately obvious. Hence groups with at least two plausible and/or correct members will select among proposed plausible or correct hypotheses only, whereas groups with only one or no plausible or correct member will select among all proposed hypotheses, plausible, correct, and nonplausible.

Postulate 7: The distribution of group member hypotheses determines the group hypothesis:

Postulate 7a: If all group members propose the same hypothesis the group proposes that hypothesis.

Postulate 7b: If a majority of group members propose the same hypothesis the group follows a compromise between a majority process and a proportionality process.

Postulate 7c: If two subgroups of equal size each propose a different hypothesis the group follows a proportionality process.

Postulate 7d: If a plurality of group members propose the same hypothesis the group follows a compromise between a plurality process and a proportionality process.

Postulate 7e: If all group members propose a different hypothesis the group follows a proportionality process and proposes a new hypothesis with probability 1/S (where S = group size).

There are five possible distributions of member hypotheses in a group: (1) a unanimity, (2) a majority, (3) two or more subgroups of equal size (with at least two members per subgroup), (4) a plurality, and (5) each member proposes a different hypothesis. Beginning with the pioneering research of Bales (1950) a number of theorists (e.g., Fiedler, 1967; Hare, 1973) have proposed that group interaction involves two fundamental processes, a task-oriented or instrumental process directed to solving the problem or making the decision at hand, and a socio-emotional or expressive process directed at maintaining harmonious group member relations. McGrath (1984) reviews these theories and integrates a number of them in his concept of a unifed task and interpersonal circumplex. Postulate 7 applies this basic idea to specifiy the social combination process for the five possible types of distributions of group member hypotheses.

If all members propose the same hypothesis there is no conflict between the task and maintenance functions. Accordingly, Postulate 7a states that the group proposes the hypothesis favored by all of the unanimous group members.

If a majority of members propose the same hypothesis the task function suggests that the group propose the hypothesis favored by the majority and follow a majority social combination process, but the interpersonal function suggests that the group should also consider the hypotheses proposed by the minority and follow a proportionality process. Accordingly, Postulate 7b states that the group follows a compromise between a majority process and a proportionality process.

If two subgroups of equal size each propose a different hypothesis both the task function and the interpersonal function suggest that the group should follow a proportionality process. Accordingly, Postulate 7c states that the group follows a proportionality process.

If a plurality of members propose the same hypothesis the task function suggests that the group should propose the hypothesis favored by the plurality and follow a plurality social combination process, but the interpersonal function suggests that the group should also consider the hypotheses proposed by the other group members and follow a proportionality process. Accordingly, Postulate 7d proposes that the group follows a compromise between a plurality process and a proportionality process.

If all group members propose different hypotheses the task function and maintenance function both suggest a proportionality process. Postulate 5 states that these groups will also propose a new emergent group hypothesis with probability 1/S. Hence Postulate 7e states that the group follows a proportionality process and proposes a new hypothesis with probability 1/S.

Finally, Postulates 7b and 7d are consistent with observations by political theorists on electoral systems. Majority, plurality otherwise, electoral systems such as those of the United States assure that the will of the majority or plurality is represented, but do not assure that the opinions of the minority are represented. Conversely, proportional electoral systems such as those of many European parliamentary democracies assure that the opinions of the minority are represented, but do not assure that the will of the majority or plurality is represented. This has been stated as "Duverger's Law": "The more accurate the representation of opinions, the less accurate the representation of wills, and vice versa (Duverger, 1984, p. 34)." Postulates 7b and 7d assume that small groups resolve this conflict between representation of opinions and wills by a compromise between majority, plurality otherwise, and proportionality social combination processes.

Predictions

A Rule Induction Task

A rule induction task was designed to abstract the two essential aspects of hypothesis formation and hypothesis evaluation in collective induction. The task required the induction of a rule that partitioned a deck of 52 standard playing cards with four suits (clubs, diamonds, hearts, and spades) of 13 cards (ace, ..., king) into examples and nonexamples of the rule. Aces were assigned the numerical value of 1, deuces 2, ..., jacks 11, queens 12, kings 13. Instructions stated that the rule could be based on suit (e.g., "diamonds"), number (e.g., "eights"), or any combination of operations on suit and number (e.g., "diamond or spade eights," "even diamonds or odd spades," or "diamonds and spades alternate"). The problems began with a card that was known to be an example of the rule face up on a table (e.g., the eight of diamonds for the rule "two diamonds and two spades alternate"). On each trial each of four group members first wrote a hypothesis on their individual hypothesis sheet. The group then discussed to consensus on a single group hypothesis, which one randomly selected group member recorded on a group hypothesis sheet. The group then played any of the 52 cards. If the card was an example of the rule it was placed face up to the right of the known example, and if the card was a nonexample of the rule it was placed below the known example, generating a progressive array of evidence (and eliminating demands on memory). Each member then made a second hypothesis, followed by a second group hypothesis and a second card play. This procedure continued for a series of trials, followed by the final member hypotheses and group hypothesis. There was no feedback on the hypotheses until after the final group hypothesis.

Figure 1 gives an illustration for the correct rule "two red cards (diamonds or hearts) and one black card (clubs or diamonds) alternate." The known initial example is the eight of diamonds. The abbreviations are D for diamonds, C for clubs, H for hearts, S for spades, A for ace, J for jack, Q for queen, K for king.

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Insert Figure 1 about here

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Predicted Probabilities of Group Hypotheses from Seven Postulates

How does this rule induction task relate to the seven postulates? All proposed hypotheses are either plausible or nonplausible. Plausible hypotheses are consistent with the array of examples and nonexamples, whereas nonplausible hypotheses are inconsistent with at least one example or nonexample (e.g., the hypothesis "diamonds" when a diamond has been a nonexample or a spade has been an example). In an experiment one of the plausible hypotheses is designated as correct. The group members begin the inductive task with consensus on the basic verbal and mathematical system, including the meaning of concepts (e.g., suit, number, diamonds, ace, 1), the mapping of cards onto numerical values, (e.g., ace = 1), and the meaning of numerical and logical operations (e.g., addition, greater than, alternation), thus fulfilling Postulate 3a. There is always sufficient information in the array of example and nonexample cards to demonstrate the plausibility or nonplausibility of a proposed hypothesis. However, there is never sufficient information to demonstrate that a given plausible hypothesis (including the single correct plausible hypothesis) is uniquely correct relative to some other plausible hypothesis. Thus, the rule induction task is near the intellective end of the task continuum and fulfills Postulate 3b for plausible hypotheses (including the single correct hypothesis) relative to nonplausible hypotheses. In contrast, the task is near the judgmental end of the continuum and does not fulfill Postulate 3b for plausible hypotheses (including the single correct hypothesis) relative to other plausible hypotheses, or for nonplausible hypotheses relative to other nonplausible hypotheses. The group members should have sufficient knowledge of the system to accept a demonstration that a proposed plausible hypothesis is plausible or a proposed nonplausible hypothesis is nonplausible, thus fulfilling Postulate 3c. Fulfillment of Postulate 4d depends upon the ability and motivation of the group members, the difficulty of the correct rule, and the available time.

On each trial one to all group members may propose the correct hypothesis, a given plausible (but not correct) hypothesis, or a given nonplausible hypothesis. The following test of the theory used four-person groups. Using subscripts to denote the number of members who propose the correct hypothesis (C_n), a given plausible hypothesis (P_n), and a given nonplausible hypothesis (N_n), there are 38 possible distributions of member preferences on each trial in four-person groups: C_4, C_3P_1, C_3N_1, ... ,

$N_1N_1N_1N_1$. The group hypothesis may be C, P_4, P_3, P_2, P_1, $P_\emptyset$ (a plausible group hypothesis not proposed by any member on that trial), N_4, N_3, N_2, N_1, or $N_\emptyset$ (a nonplausible group hypothesis not proposed by any member on that trial).

The theory predicts the conditional probabilities of each possible group hypothesis for each of the 38 distributions of member hypotheses. Table 2 gives these predicted conditional probabilities. Assuming Postulates 1 through 4, the predictions for each row in Table 2 are specifically derived from Postulates 5, 6, and 7.

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Insert Table 2 about here

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First, consider Postulate 5. In the first 11 distributions, C_4 through $C_1P_2N_1$, at least two members propose the same hypothesis, so the group selects among only those hypotheses proposed by the group members. In the 12th distribution, $C_1P_1P_1P_1$, no two members propose the same hypothesis, so the group selects among the hypotheses proposed by the group members and proposes a new emergent hypothesis with probability 1/S = 1/4 = .25. Similar predictions are derived from Postulate 5 for the 26 remaining distributions.

Second, consider Postulate 6. In the first 15 distributions, C_4 through $C_1P_1N_1N_1$, at least two members propose plausible and/or correct hypotheses, so the group selects among the proposed plausible and/or correct hypotheses only. In the 16th distribution, C_1N_3, only one member proposes a plausible or correct hypothesis, so the group selects among all proposed hypotheses. Similar predictions are derived from Postulate 6 for the remaining 21 distributions.

Third, consider Postulate 7. Recall that there are five possible types of distributions of member hypotheses. Postulates 7a, 7b, 7c, 7d, and 7e apply to these five types of distributions, respectively. The first examples of these five types of distributions are C_4, C_3P_1, C_2P_2, $C_2P_1P_1$, and $C_1P_1P_1P_1$, respectively, so we consider them as illustrative examples of the derivations of the conditional probabilities.

In the C_4 distributions all group members propose the same hypothesis, so the predicted probability of the C group hypothesis from Postulate 7a is 1.00. The predicted probabilities of the P_0 and N_0 group hypotheses are .000. In the C_3P_1 distribution a majority of group members propose the same hypothesis, so Postulate 7b predicts a probability of .875 for the C group hypothesis as a compromise between the prediction of 1.00 from a majority process and the prediction of .75 from a proportionality process. Similarly, Postulate 7b predicts a probability of .125 for the P_1 group hypothesis as a compromise between the prediction of .00 from a majority process and the prediction of .25 from a proportionality process. In the C_2P_2 distribution two subgroups of group members of equal size each propose a different hypothesis, so Postulate 7c predicts a probability of .50 for each of the C and P_2 group hypotheses. In the $C_2P_1P_1$ distribution a plurality of group members propose the same hypothesis, so Postulate 7d predicts a probability of .75 for the C group hypothesis as a compromise between the prediction of 1.00 from a plurality process and the prediction of .50 from a proportionality process. Similarly, Postulate 7d predicts a probability of .25 for the P_1 group hypothesis as a compromise between the prediction of .00 from a plurality process and the prediction of .50 from a proprtionality process. In the $C_1P_1P_1P_1$ distribution all group members propose a different hypothesis, so Postulate 7e predicts a probability of .188 for the C group hypothesis, a probabiliy of .563 for the P_1 group hypothesis, and a probability of .25 for the emergent group hypothesis, P_0.

<u>Predicted Probabilities of Group Hypotheses from Proportionality Social Combination Process Among Correct and Plausible Hypotheses</u>

Different predicted probabilities of group hypotheses may be derived from two other sets of plausible assumptions about the social combination process in collective induction. First, on the assumption that the rule induction task is at the intellective end of the task continuum, a single correct or plausible member would suffice to demonstrate the nonplausibility of any proposed nonplausible hypotheses, no matter how many members proposed them. Since there would be no reason to prefer any plausible hypothesis or the correct hypothesis over any other plausible hypothesis, the group would follow a proportionality process among correct and plausible hypotheses only. Table 3 gives the predicted probabilities of the group responses from this set of assumptions about the social combination process.

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Insert Table 3 about here

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<u>Predicted Probabilities of Group Hypotheses from Majority, Plurality Otherwise, Proportionality Otherwise, Social Combination Process Among All Proposed Hypotheses</u>

On the assumption that the inductive task is at the judgmental end of the task continuum, the group would select among all proposed hypotheses, correct, plausible, or nonplausible. The group would follow a majority process if there were a majority, a plurality process if there were a plurality, and a proportionality process if there were no plurality. Table 4 gives the predicted probabilities of the group hypotheses from this set of assumptions about the social combination process.

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Insert Table 4 about here

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In summary, the obtained probabilities of the 11 types of group hypotheses for the 38 types of distributions of member hypotheses should correspond more closely to the probababilities derived from the proposed theory (Table 2) than to the probabilities derived from two other plausible theories (Tables 3 and 4).

<u>Predicted Transition Probabilities from Group Hypotheses on Trial t to Group Hypotheses on Trial t+1</u>

In addition to the social combination processes on trial _t_ the seven postulates predict the transition probabilities from group hypotheses on trial _t_ to group hypotheses on trial _t_+1. A correct, plausible, or nonplausible group hypothesis on trial _t_ may be followed by a correct, plausible, or nonplausible group hypothesis on trial _t_+1. Postulates 5 and 6 state that the group will propose nonplausible hypotheses only if one or no members propose the correct hypothesis or a plausible hypothesis. This leads to two predictions. First, the transition probability from a nonplausible hypothesis on trial _t_ to another nonplausible hypothesis on trial _t_+1 should be much lower than the transition probability from a correct hypothesis on trial _t_ to a correct hypothesis on trial _t_+1 or the transition probability from a plausible hypothesis on trial _t_ to a plausible hypothesis on trial *t*+1. Second, the transition probabilities from a nonplausible hypothesis on trial *t* to a correct or plausible hypothesis on trial *t*+1 should be higher than the transition probabilities from a correct or plausible hypothesis on trial *t* to a nonplausible hypothesis on trial *t*+1.

Predicted Order of Proportions of Confirming and Disconfirming Card Selections for Five Types of Hypotheses

Until now we have considered group hypothesis formation. The other essential aspect of collective induction is hypothesis evaluation. In the rule induction task each card selection may be considered an experiment to evaluate the current group hypothesis. There are five possible types of relationships between the proposed hypothesis and the correct rule: Type 1: the proposed hypothesis is plausible and based on the same relationships as the correct rule but too specific (e.g., the hypothesis "diamonds and spades alternate" for the correct rule "red and black alternate"); Type 2: the proposed hypothesis is plausible but based on a different set of relationships than the correct rule (e.g., the hypothesis "even numbers" for the correct rule "red and black alternate"); Type 3: the proposed hypothesis is plausible and based on the same relationships as the correct rule but too general (e.g., the hypothesis "red and black alternate" for the correct rule "diamonds and spades alternate"); Type 4: the proposed hypothesis is nonplausible (e.g., the hypothesis "diamonds" when a diamond has been a nonexample or a spade has been an example of the correct rule "diamonds and spades alternate"); Type 5: the proposed hypothesis is the single correct rule.

For each of these five types the card play may be chosen to confirm the hypothesis or disconfirm the hypothesis. To illustrate, given the correct hypothesis "red and black alternate," an array of four successive examples in the order "diamond, spade, diamond, spade," and the hypothesis "diamonds and spades alternate," a diamond may be played to confirm the proposed hypothesis and a spade may be played to disconfirm the proposed hypothesis (see Klayman & Ha, 1987, for an excellent demonstration of the relationships between confirmation, disconfirmation, and information in hypothesis testing).

The relative order of the proportion of disconfirming card plays for the five possible types of hypotheses may be derived from Postulates 5, 6, and 7. A nonplausible hypothesis (Type 4) fails to correspond with the entire evidence set. Postulates 5 and 6 predict that the group will propose nonplausible hypotheses only if one or no members propose the correct hypothesis or a plausible hypothesis. The member who does propose a correct or plausible hypothesis should suggest that the group play a card to disconfirm the proposed nonplausible hypothesis, so the highest proportion of disconfirming card plays should be for (Type 4) nonplausible hypotheses.

A majority of the group members should be more likely to propose the correct hypothesis (Type 5) and the two types of plausible hypotheses that are based on the same relationships as the correct hypothesis but are too specific (Type 1) or too general (Type 3) than plausible hypotheses that are based on other relationships than the correct hypothesis (Type 2). Postulate 7b states that these groups will follow a compromise between a majority and proportionality process. Thus the minority is more likely to suggest that the group play a card to disconfirm a proposed Type 2 group hypothesis than a Type 1, Type 3, or Type 5 hypothesis. Postulates 7c and

7d predict a similar result for one of two equal subsets or a plurality of members who propose a Type 2 group hypthesis.

By the same reasoning, a minority of group members should be more likely to suggest that the group play a card to disconfirm a proposed Type 1 or Type 3 group hypothesis than a Type 5 hypothesis, because the correct hypothesis will always be a plausible alternative to a hypothesis that is too specific or general. In contrast, a hypothesis that is too specific or too general will be less likely to be a plausible alternative to the correct hypothesis, especially in the latter trials when the correct hypothesis has remained plausible after previous Type 1 and Type 3 hypotheses have been eliminated. Finally, the theory does not predict a difference in the proportion of disconfirming card plays for Type 1 and Type 3 hypotheses.

In summary, the proportion of disconfirming card selections should be in the following order for the five types of hypotheses:

Type 4 > Type 2 > (Type 1 = Type 3) > Type 5.

Predicted Probability of Correct Group Hypotheses on Trial t+1 Conditioned on Five Types of Confirming and Disconfirming Card Selections on Trial t

The objective of the rule induction task is to propose the correct hypothesis. How does the evaluation of hypotheses by confirming and disconfirming card selections relate to the achievement of this objective? In his influential work The Logic of Scientific Discovery Popper (1959) proposed that the criterion of demarcation between scientific and nonscientific theory is falsifiability. Scientific experiments should therefore be designed to disconfirm rather than confirm prevailing theory. In the rule induction task each hypothesis may be considered a prevailing theory and each card play an experiment designed to disconfirm or confirm it. Popper's position would predict that the conditional probability of a correct hypothesis on trial _t_+1 should be higher following a card play designed to disconfirm the hypothesis on trial _t_ than following a card play designed to confirm the hypthesis on trial _t_. However, this prediction may not apply to all of the five types of hypotheses.

Type 1 and Type 3 hypotheses are plausible and based on the same relationships as the correct hypothesis but too specific or too general. A card play designed to disconfirm the hypothesis on trial _t_ may in fact disconfirm it. The group may then abandon the too specific or too general hypothesis and propose the correct hypthesis on trial _t_+1. In contrast, a card play designed to confirm the hypothesis is less likely to disconfirm it, so that the group will continue to propose the too specific or too general hypothesis on trial _t_+1. Thus, there should be a higher probability of a correct hypothesis on trial _t_+1 following a card play designed to disconfirm a Type 1 or Type 3 hypothesis.

Type 2 hypotheses are plausible but based on different relationships than the correct hypothesis. Although card plays designed to disconfirm Type 2 hypotheses are more likely to disconfirm them than are card plays designed to confirm them, such disconfirmation will not necessarily increase the probability of a correct hypothesis on trial _t_+1. Rather, the group may continue to propose other Type 2 hypotheses on trial _t_+1. For example, given the correct rule "diamonds and spades alternate," disconfirmation of the Type 2 hypothesis "even diamonds" by the play of the jack of diamonds on trial _t_ may lead to the Type 2 hypothesis "even diamonds below the jack" on trial _t_+1.

As previously proposed, there should be more disconfirming card plays on trial _t_ for Type 4 nonplausible hypotheses than for the other four types of hypotheses. However, to the extent these disconfirming card plays disconfirm the nonplausible hypotheses under consideration rather than plausible hypotheses not under consideration, they should not increase the probability of a correct group hypothesis on trial _t+1_.

The correct (Type 5) hypothesis is a subset of the plausible hypotheses. Once the correct (Type 5) hypothesis is proposed, it will necessarily be consistent with either a confirming or disconfirming card play on trial _t_. Since the correct group hypothesis will be consistent with any card play on trial _t_, it cannot be falsified, so there is no reason to abandon the correct hypthesis on trial _t+1_. Such a win-stay, lose-shift strategy would predict a high transition probability from a correct hypothesis on trial _t_ to another correct hypthesis on trial _t+1_ . Thus, the probability of a correct hypothesis on trial _t_ should not differ following a card selection designed to confirm or disconfirm a correct (Type 5) group hypothesis on trial _t_.

In summary, card plays designed to disconfirm the hypothesis on trial _t_ should result in a higher probability of a correct hypothesis on trial _t+1_ for Type 1 and Type 3 hypotheses, but not for Type 2, Type 4, or Type 5 hypotheses.

Method

Four hundred four-person groups each solved one rule induction problem.[1] The members of these groups were 1,600 college students in introductory psychology courses, 1,376 at the University of Illinois at Urbana-Champaign and 224 at Texas Tech University.

The rules involved alternating patterns of three, four, or five cards of specified suits (clubs, diamonds, hearts, spades) or colors (black clubs or spades, red diamonds or hearts), such as "two black cards and one red card alternate," "diamond, heart, club, spade alternate," or "four spades and one diamond alternate." Pilot work indicated that rules with patterns of three cards were relatively easy, patterns of four cards were relatively difficult, and patterns of five cards were quite difficult. Accordingly, 276 groups had rules with patterns of four cards, 64 with patterns of three cards, and 60 patterns of five cards. There were 34 different rules.

The experimenter sat at a table with the subjects and instructed them (from memory) as follows:

> This is an experiment in problem solving. The objective is to figure out an arbitrary rule that divides an ordinary deck of 52 playing cards into examples and nonexamples of the rule. Aces are defined as 1, deuces as 2, and so on up to tens as 10, jacks as 11, queens as 12, and kings as 13. The rule may be based on any characteristics of the cards, including suit, number, numerical and logical operations, alternation, and so on. For example, the rule might be "diamonds," so that all diamonds would be examples and all hearts, clubs, and spades would be nonexamples. I will start you with an example of the rule, face up on the table. For example, this eight of diamonds would be an example of the rule "diamonds." The first step will be for each of you to write your first hypothesis on your individual hypothesis sheet. Then the four of you will decide on a group hypothesis, which one of you will write on this group hypothesis sheet. We will determine the recorder by a roll of this die [this was done]. Then you will play any of the 52 cards you choose. If the card you play is also an example of

the rule, I will place it to the right of the known example. If the card is not an example of the rule, I will place it below the known example. Then you will each make your second individual hypothesis, make your second group hypothesis, and play a second card. If this second card is an example of the rule, I will place it to the right of the last example, and if it is not an example, I will place it below the last card played. [The experimenter then demonstrated this procedure with four sample decks of five cards each, randomly selected within the constraints of the rule, for the four example rules "diamonds," "even diamonds," "even diamonds or clubs above the six," and "odd spades alternate with even hearts."] This procedure will continue for 10 (15 for 128 groups) trials of individual hypotheses, group hypothesis, and group card play. After the 10 (15) trials you will make your final individual hypotheses and your final group hypothesis. I will not say whether or not your hypotheses are correct during the experiment, but will tell the correct hypothesis afterwards.

Subjects were scheduled on the hour and told they had until ten minutes before the following hour to solve the problem (pilot work indicated this was sufficient time, fulfilling part of Postulate 4d). After the feedback on the card play the four persons proposed their own next hypotheses without discussion, and then discussed freely on the group hypothesis and card play. Any member could inspect the hypothesis sheet of any other member or the group at any time. No decision rule (e.g., unanimity, majority) for either hypotheses or card plays was imposed or implied by the instructions. As many decks of cards as desired were available, so that a given card could be played more than once. The decks were sorted by suits and arranged in ascending order from the ace to the king to facilitate finding a given card.

Afterwards the experimenter explained the purpose of the research to the subjects, gave them a written explanation with a reference for further reading if interested, thanked them for participating, and asked them not to discuss the experiment with potential future participants.

Results

Tests of Postulates 5 and 6

Postulate 5 states that if no two members propose the same hypothesis the group selects among the hypotheses proposed by the group members and proposes a new emergent group hypothesis with probability 1/S (where S is group size). Over the nine distributions ($C_1P_1P_1P_1$, $C_1P_1P_1N_1$, ..., $N_1N_1N_1N_1$) where no two members proposed the same hypthesis, aggregating over C, $P_\emptyset$, and $N_\emptyset$ group hypotheses as appropriate, the conditional probability of a new emergent group hypothesis was 256/845 = .303. Over the 31 distributions where at least two members proposed the same hypothesis the conditional probability of a new emergent group hypothesis was 177/3976 = .045. These results offer strong support for Postulate 5.

Postulate 6 states that if at least two members propose plausible and/or correct hypotheses the group selects among plausible and/or correct hypotheses only, but if one or no members propose a plausible or correct hypothesis the group selects among all proposed hypotheses. The conditional probabilities of a plausible or correct group hypothesis given a distribution with two or more plausible and/or correct members, one plausible or correct member, or no plausible or correct members, were 4433/4580 = .968, 54/137 = .394, and 4/104 = .038, respectively. These results offer strong support for Postulate 6.

Probabilities of Group Hypotheses

Table 5 gives the probabilities of the 11 possible group responses for the 38 possible distributions of member hypotheses.

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Insert Table 5 about here

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The predicted proportions of group hypotheses were computed for each of the three theories by multiplying the predicted conditional probability of each response from Table 2, Table 3, or Table 4 by the obtained row sum for each distribution of member hypotheses and dividing by the total number of group hypotheses (4821). For example, the predicted proportion of correct (C) group responses for the C_3P_1 distribution was .875 x 106/4821 = .0192 from the seven postulates (Table 2), .750 x 106/4821 = .0165 from a proportionality social combination process for correct and plausible hypotheses (Table 3), and 1.000 x 106/4821 = .0220 from a majority, plurality otherwise, proportionality otherwise social combination process for all hypotheses (Table 4). Table 5 gives the sums of squared predicted minus obtained proportions of the possible group hypotheses for each of the 38 distributions of member hypotheses for each of the three theories. For example, the values for the C_4 distribution are the sum of squared predicted minus obtained proportions for the C, P_0, and N_0 group hypotheses, the values for the C_3P_1 distribution are the sum of squared predicted minus obtained proportions for the C, P_1, P_0, and N_0 group hypotheses, and so on.

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Insert Table 6 about here

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Inspection of Tables 2, 3, and 4 indicates that the three theories make identical predictions for 10 distributions (C_4, C_3N_1, C_2P_2, $C_2N_1N_1$, P_4, P_3N_1, P_2P_2, $P_2N_1N_1$, N_4, and N_2N_2) and different predictions for the other 28 distributions. Table 6 indicates that the seven postulates made the most accurate prediction for 15 of these 28 distributions; proportionality made the most accurate predictions for four distributions; majority, plurality otherwise, proportionality otherwise made the most accuracte predictions for four distributions. The seven postulates and one of the other theories made equally accurate predictions for four distributions. One distribution, C_2N_2, did not occur.

The bottom row of Table 6 gives the square root of the sum of the squared predicted minus obtained proportions for each of the three theories. These values were .0280 for the seven postulates, .0622 for proportionality among correct and plausible hypotheses, and .0684 for majority, plurality otherwise, proportionality otherwise among correct, plausible, and nonplausible hypotheses.

In summary, the predictions from the seven postulates fit the obtained social combination processes quite well, and better than the predictions from two other plausible theories, each with considerable support in previous research on tasks at the intellective or judgmental ends of the group task continuum of Postulate 2.

Transition Probabilities from Group Hypotheses on Trial t to Group Hypotheses on Trial t+1

Figure 2 gives the transition probabilities from correct, plausible, and nonplausible group hypotheses on trial *t* to correct, plausible, and nonplausible group hypotheses on trial *t*+1. The two predictions from

Postulates 5 and 6 were supported. First, the transition probability of .41 from a nonplausible hypothesis on trial _t_ to another nonplausible hypothesis on trial _t_+1 was much lower than the transition probability of .96 from a correct hypothesis on trial _t_ to a correct hypothesis on trial _t_+1 or the transition probability of .88 from a plausible hypothesis on trial _t_ to a plausible hypothesis on trial _t_+1. Second, the transition probabilities of .10 and .49 from a nonplausible hypothesis on trial _t_ to a correct or plausible hypothesis on trial _t_+1 were higher than the transition probabilities of .00 and .06 from a correct or plausible hypothesis on trial _t_ to a nonplausible hypothesis on trial _t_+1.

Insert Figure 2 about here

Proportions of Confirming and Disconfirming Card Selections for Five Types of Group Hypotheses

Table 7 gives the proportions of confirming and disconfirming card selections for the five types of hypotheses. The proportions of disconfirming card selections of .382 for Type 4 (nonplausible), .339 for Type 2 (plausible based on other relationships), .225 for Type 1 (plausible, too specific), .200 for Type 3 (plausible, too general), and .109 for Type 5 (correct) were in the exact order predicted from Postulates 5, 6, and 7.

Table 7 also gives the overall proportions of confirming and disconfirming selections and the overall proportions of the five types of hypotheses. Proportions of .172 were correct (Type 5), .759 plausible (Types 1, 2, and 3), and .069 nonplausible (Type 4). The low proportion of nonplausible hypotheses is support for Postulates 5 and 6. The relative proportions of correct and plausible hypotheses reflect the range of relatively difficult rules. The higher proportion of too specific plausible Type 1 hypotheses than too general plauisble Type 3 hypotheses may be due to the nature of the rules. Of the 400 groups, 244 had rules based on color (e.g., "two red and two black alternate") and 156 rules based on suit (e.g., "diamond, heart, club, spade alternate"), so that there would be relatively more opportunity for Type 1 hypotheses. It may also reflect a tendency for both group members and groups to propose inductions that are too specific and limited rather than inductions that are too general and unlimited.

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Insert Table 7 about here

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<u>Group Hypotheses on Trial t+1 Conditioned on Card Selections on Trial t</u>

Table 8 gives the probabilities of correct, plausible, and nonplausible group hypotheses on trial *t*+1 conditioned on the five types of confirming and disconfirming card selections on trial *t*. As predicted, the probability of a correct group hypothesis on trial *t*+1 was greater after a disconfirming than confirming Type 1 card selection (.422 vs. .104). There were only 16 confirming and four disconfirming Type 3 card selections, too few to test the predicted difference. As predicted, there was little difference in the probability of a correct group hypothesis on trial *t*+1 after disconfirming or confirming Type 2 (.055 vs .038), Type 4 (.080 vs. .069), or Type 5 (.962 vs .928) card selections. In summary, card selections designed to disconfirm the current hypothesis increased the probability of a subsequent correct hypothesis only for hypotheses that were based on the same relationships as the correct hypothesis but were too specific.

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Insert Table 8 about here

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Discussion

The seven postulates of the theory set collective induction within a general social combination approach to group problem solving and decision making on a continuum of group tasks (Postulates 1 and 2) and a general relationship between the demonstrability of proposed group responses and the number of group members that is necessary and sufficient for a group response (Postulates 3 and 4), and formalize three specific sets of assumptions of the particular social combination process in collective induction (Postulates 5, 6, and 7). The support for Postulates 1 through 4 in the literature on group problem solving and decision making was reviewed in the first part of this article, and the results provide support for Postulates 5 through 7. Postulates 5 and 6 were supported by the corresponding conditional probabilities (recall the first section of the results), and Postulate 7 by the fit between the predicted and obtained probabilities of the 11 types of group responses for the 38 distributions of group member hypotheses (recall Tables 2, 5, and 6). In addition to this fit for the predicted and obtained probabilities of the the group responses, three other sets of predictions were derived from Postulates 5, 6, and 7 and supported by the results. These were the transition probabilities from group hypotheses on trials _t_ to _t_+1, the order of the proportions of disconfirming card selections for the five types of group hypotheses, and the conditional probabilities of a correct group hypothesis on trial _t_+1 given disconfirming card selections on trial _t_.

As indicated in Table 6 the poorest fit for the seven postulates was the $P_2P_1P_1$ distribution, with an overpredicted probability of .750 relative to the obtained probability of .622 for the P_2 group hypothesis and an underpredicted probability of .000 relative to the obtained probability of .093 of the P_0 group hypothesis. This indicates that distributions where all members propose plausible hypotheses and only two of the four members agree on a given hypothesis are somewhat more likely than predicted from Postulate 5 to propose a new emergent hypothesis. The second poorest fit was for the $P_1P_1N_1N_1$ distribution, with an overestimated probability of .750 relative to the obtained probability of .447 for the P_1 group hypothesis and an underestimated probability of .000 relative to the obtained probability of .228 of the N_1 group hypothesis. This indicates that in distributions where all members propose different hypotheses, two plausible and two nonplausible, the groups are somewhat less likely than predicted from Postulate 6 to select only the proposed plausible hypotheses.

The underlying logic of a social combination approach is to formalize a set of assumptions as a group decision scheme (Smoke & Zajonc, 1962) or social decision scheme (Davis, 1973) that specifies the probabilities of a set of mutually exclusive and exhaustive group responses conditioned on a set of mutually exclusive and exhaustive distributions of group member preferences. Different sets of assumptions generate different predicted conditional probabilities of group responses, so that the fit between predicted and obtained probabilities provides differential support for the underlying theories. In the current research the predictions from the seven postulates were tested against two other sets of assumptions with strong support in the previous literature on tasks near the intellective or judgmental ends of the group task continuum.

A social combination approach is a different level of theory than theories based on a direct observation of the group process or process theories of interpersonal influence. A social combination approach competively tests the logical consequences of different sets of assumptions of the group process rather than directly observes the group process. In the present research the obtained probabilities of group hypotheses for different distributions of member hypotheses indicate an orderly underlying social combination process that is consistent with the proposed theory. The results clearly show what groups do in collective induction on one level of theory. Further research with direct observation of the group processes may give a fuller understanding of why the process is so orderly. Likewise, further research may relate collective induction to theories of interpersonal influence (e.g., Hastie, Penrod, & Pennington, 1984; Paulus, 1980, in press) and information processing (e.g., Stasser & Titus, 1985, 1987). As with theoretical understanding at different levels in any domain, social combination theories and theories based on direct observation of group process, interpersonal influence, and collective information processing are complementary rather than rival explanations.

This complementarity between social combination theories and process theories may be illustrated by research on the group choice shift. The two currently prevailing process theories are persuasive arguments theory (e.g., Burnstein, 1982, Vinokur & Burnstein, 1974) and social comparison theory (e.g., Goethals & Zanna, 1979; Sanders & Baron, 1977). Laughlin and Earley (1982) derived different predictions of the best-fitting social combination process on items known to produce strong or moderate risky or conservative shifts from these two theories. On items known to produce strong shifts, both theories predict a majority social combination process, whereas on items with moderate shifts persuasive arguments theory predicts a risk-supported or conservative-supported social combination process and social comparison theory predicts a majority process. The results supported the predictions of persuasive arguments theory on items with moderate shifts.

The first paragraph of this article proposed that many small groups, such as scientific researchers, weather forecasters, petroleum geologists, securities analysts, or air crash investigators, seek collective inductions. Would the current theory and results with college students on the rule induction task generalize to such groups? The members of such groups are intelligent, motivated, and highly educated people. They were also at one time college students, another population of intelligent, motivated, and relatively educated people. I would predict that the same orderly social combination processes that applied to college students in the present research would also apply to these former college students on the same rule induction task. The task is interesting and motivating for college students, and I believe it would be interesting and motivating for scientific research teams and other such groups. The rule may be based on any combination of numerical and logical operations on suit and number, and may be as complex and challenging as the interest of the investigator and the competence of the group require.

The basic issue for the generalizability of the task is the extent to which the task abstracts the essential aspects of collective induction. I have addressed this issue previously:

In my opinion the rule induction task is an elegant abstraction of the essential aspects of "real-world" collective induction. Each hypothesis models a proposed generalization or tentative theory and each card play models an experiment or observation designed to test predictions from the proposed generalization. The large number of initially plausible hypotheses models the large number of initially plausible theories in a domain. The progressive array of examples and nonexamples models the progressive growth of evidence and the corresponding progressive reduction in the number of plausible theories. The social combination processes model the collective search for generalizations, rules, and principles.

Even the arbitrary designation of one of the plausible hypotheses as correct ultimately models "real-world" induction. The paradox of experimental research on induction is that some criterion of certainty is imposed upon plausibility. But this is also the paradox of all demonstrative knowledge. The certain conclusions from formally valid deduction ultimately rest upon previous social consensus on the accepted propositions that constitute the premises. And, previous social consensus on these accepted propositions also imposed certainty upon plausibility. (Laughlin, 1988, p. 266).

References

Bales, R. F. (1950). Interaction process analysis: A method for the study of small groups. Chicago: University of Chicago Press.

Black, D. (1958). The theory of committees and elections. Cambridge, Eng.: Cambridge University Press.

Bond, C. F., Jr., & Titus, L. J. (1983). Social facilitation: A meta-analysis of 241 studies. Psychological Bulletin, 94, 265-292.

Bottger, P. C., & Yetton, P.W. (1988). An integration of process and decision scheme explanations of group problem solving performance. Organizational Behavior and Human Decision Processes, 42, 234-249.

Burnstein, E. (1982). Persuasion as argument processing. In H. Brandstätter, J. H. Davis, & G. Stocker-Kreichgauer (Eds.), Group decision making (pp. 103-124). London: Academic Press.

Castore, C. H., & Murnighan, J. K. (1978). Determinants of support for group decisions. Organizational Behavior and Human Performance, 22, 75-92.

Crott, H. W., Zuber, J. A., & Schermer, T. (1986). Social decision schemes and choice shift: An analysis of group decisions among bets. Journal of Experimental Social Psychology, 22, 1-21.

Cvetkovich, G., & Baumgardner, S. R. (1973). Attitude polarization: The relative influence of discussion group structure and reference group norms. Journal of Personality and Social Psychology, 26, 159-165.

Davis, J. H. (1973). Group decision and social interaction: A theory of social decision schemes. Psychological Review, 80, 97-125.

Davis, J. H. (1980). Group decision and procedural justice.

In M. Fishbein (Ed), Progress in social psychology (pp. 157-229). Vol. 1. Hillsdale, N. J.: Erlbaum.

Davis, J. H. (1982). Social interaction as a combinatorial process in group decision. In H. Brandstätter, J. H. Davis, & G. Stocker-Kreichgauer (Eds), Group decision making (pp. 27-58). London: Academic Press.

Davis, J. H., Hornik, J. A., & Hornseth, J. P. (1970). Group decision schemes and strategy preferences on a sequential response task. Journal of Personality and Social Psychology, 15, 397-408.

Davis, J. H., Kerr, N. L., Atkin, R. S., Holt, R., & Meek, D. (1975). The decision processes of 6- and 12-person juries assigned unanimous and 2/3 majority rules. Journal of Personality and Social Psychology, 32, 1-14.

Davis, J. H., Kerr, N. L., Stasser, G., Meek, D., & Holt, R. (1977). Victim consequences, sentence severity, and decision processes in mock juries. Organizational Behavior and Human Performance, 18, 346-365.

Davis, J. H., Kerr, N. L., Sussmann, R., & Rissman, A. K. (1974). Social decision schemes under risk. Journal of Personality and Social Psychology, 30, 248-271.

Davis, J. H., & Restle, F. (1963). The analysis of problems and prediction of group problem solving. Journal of Abnormal and Social Psychology, 66, 103-116.

Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. Journal of Personality and Social Psychology, 53, 497-509.

Duverger, M. (1984). Which is the best electoral system? In A.

Lijphart & B. Grofman (Eds.), Choosing an electoral system (pp. 31-39). New York: Praeger.

Einhorn, H. J., Hogarth, R. M., & Klempner, E. (1977). Quality of group judgment. Psychological Bulletin, 84, 158-172.

Faust, W. L. (1959). Group versus individual problem solving. Journal of Abnormal and Social Psychology, 59, 68-72.

Fiedler, F. E. (1967). A theory of leadership effectiveness. New York: McGraw-Hill.

Goethals, G. R., & Zanna, M. P. (1979). The role of social comparison in choice shifts. Journal of Personality and Social Psychology, 37, 1469-1476.

Hackman, J. R., & Morris, C. G. (1975). Group tasks, group interaction process, and group performance effectiveness: A review and proposed integration. In L. Berkowitz (Ed.), Advances in experimental social psychology (pp. 45-99). Vol. 8. New York: Academic Press.

Hare, A. P. (1973). Theories of group development and categories for interaction analysis. Small Group Behavior, 4, 259-304.

Hastie, R. (1986). Review essay: Experimental evidence on group accuracy. In G. Owen & B. Grofman (Eds.), Information pooling and group decision making (pp. 129-157). Westport, CT: JAI.

Hastie, R., Penrod, S., & Pennington, N. (1984). Inside the jury. Cambridge, MA: Harvard University Press.

Hill, G. W. (1982). Group versus individual performance: Are N + 1 heads better than one? Psychological Bulletin, 91, 517-539.

Kaplan, M. F., & Miller, C. E. (1987). Group decision making and normative versus informational influence: Effects of type of issue and assigned decision rule. Journal of Personality and Social Psychology, 53, 306-313.

Kelley, H. H., & Thibaut, J. W. (1969). Group problem solving. In G. Lindzey & E. Aronson (Eds.), The handbook of social psychology (pp. 1-101). Vol. 4. Reading, MA: Addison-Wesley.

Kerr, N. L. (1981). Social transition schemes: Charting the group's road to agreement. Journal of Personality and Social Psychology, 41, 684-702.

Kerr, N. L. (1982). Social transition schemes: Model, method, and application. In H. Brandstätter, J. H. Davis, & G. Stocker-Kreichgauer (Eds.), Group decision making (pp. 59-79). London: Academic Press.

Kerr, N. L., Atkin, R. S., Stasser, G., Meek, D., Holt, R. W., & Davis, J. H. (1976). Guilt beyond a reasonable doubt: Effects of concept definition and assigned decision rule on the judgments of mock jurors. Journal of Personality and Social Psychology, 31, 574-593.

Kerr, N. L., Davis, J. H., Meek, D., & Rissman, A. K. (1975). Group position as a function of member attitudes: Choice shift effects from the perspective of social decision scheme theory. Journal of Personality and Social Psychology, 31, 574-593.

Kerr, N. L., & MacCoun, R. J. (1985). The effects of jury size and polling method on the process and product of jury deliberation. Journal of Personality and Social Psychology, 48, 349-363.

Klayman, J., & Ha, Y-W. (1987). Confirmation, disconfirmation, and information in hypothesis testing. Psychological Review, 94, 211-228.

Lambert, R. (1976). Situations of uncertainty: Social influence and decision processes. In H. Brandstätter, J. H. Davis, & H. Schuler

(Eds.), Dynamics of group decisions (pp. 53-66). Beverly Hills, CA: Sage.

Lamm, H., & Myers, D. G. (1978). Group-induced polarization of attitudes and behavior. In L. Berkowitz (Ed.), Advances in experimental social psychology (pp. 145-195). Vol. 11. New York: Academic Press.

Laughlin, P. R. (1980). Social combination processes of cooperative problem-solving groups on verbal intellective tasks. In M. Fishbein (Ed.), Progress in social psychology (pp. 127-155). Hillsdale, N. J.: Erlbaum.

Laughlin, P. R. (1988). Collective induction: Group performance, social combination proceses, and mutual majority and minority influence. Journal of Personality and Social Psychology, 54, 254-267.

Laughlin, P. R., & Adamopoulos, J. (1980). Social combination processes and individual learning for six-person cooperative groups on an intellective task. Journal of Personality and Social Psychology, 38, 941-947.

Laughlin, P. R., & Adamopoulos, J. (1982). Social decision schemes on intellective tasks. In H. Brandstätter, J. H. Davis, & G. Stocker-Kreichgauer (Eds), Group decision making (pp. 81-102). London: Academic Press.

Laughlin, P. R., & Earley, P. C. (1982). Social combination models, persuasive arguments theory, social comparison theory, and choice shift. Journal of Personality and Social Psychology, 42, 273-280.

Laughlin, P. R., & Ellis, A. L. (1986). Demonstrability and social combination processes on mathematical intellective tasks. Journal of Experimental Social Psychology, 22, 177-189.

Laughlin, P. R., Kerr, N. L., Davis, J. H., Halff, H. M., & Marciniak, K. A. (1975). Group size, member ability, and social decision schemes on an intellective task. Journal of Personality and Social Psychology, 31, 522-535.

Laughlin, P. R., Kerr, N. L., Munch, M. M., & Haggarty, C. A. (1976). Social decision schemes of the same four-person groups on two different intellective tasks. Journal of Personality and Social Psychology, 33, 80-88.

Laughlin, P. R., & McGlynn, R. P. (1986). Collective induction: Mutual group and individual influence by exchange of hypotheses and evidence. Journal of Experimental Social Psychology, 22, 567-589.

Lorge, I., Fox, D., Davitz, J., & Brenner, M. (1958). A survey of studies contrasting the quality of group performance and individual performance. Psychological Bulletin, 55, 337-372.

Lorge, I., & Solomon, H. (1955). Two models of group behavior in the solution of Eureka-type problems. Psychometrika, 20, 139-148.

MacCoun, R. J., & Kerr, N. L. (1988). Asymmetric influence in mock jury deliberations: Jurors bias for leniency. Journal of Personality and Social Psychology, 54, 21-33.

Marquart, D. I. (1955). Group problem solving. Journal of Social Psychology, 41, 103-113.

McGrath, J. E. (1984). Groups: Interaction and performance. Englewood Cliffs, NJ: Prentice-Hall.

Myers, D. G. (1982). Polarizing effects of social interaction. In H. Brandstätter, J. H. Davis, & G. Stocker-Kreichgauer (Eds.), Group decision making (pp. 125-161). London: Academic Press.

Myers, D. G., & Lamm, H. (1976). The group polarization phenomenon. _Psychological Bulletin_, _83_, 602-627.

Paulus, P. (Ed.) (1980). _Psychology of group influence_. Hillsdale, N.J.: Erlbaum.

Paulus, P. (Ed.) (in press). _Psychology of group influence_. 2nd. Ed. Hillsdale, N.J.: Erlbaum.

Penrod, S., & Hastie, R. (1979). Models of jury decision making: A critical review. _Psychological Bulletin_, _86_, 462-492.

Penrod, S., & Hastie, R. (1980). A computer simulation of jury decision making. _Psychological Review_, _87_, 133-159.

Popper, K. (1959). _The logic of scientific discovery_. New York: Basic Books.

Sanders, G. S., & Baron, R. S. (1977). Is social comparison irrelevant for producing choice shifts? _Journal of Experimental Social Psychology_, _13_, 303-314.

Shaw, M. E. (1932). Comparison of individuals and small groups in the rational solution of complex problems. _American Journal of Psychology_, _44_, 491-504.

Shiflett, S. (1979). Toward a general model of small group productivity. _Psychological Bulletin_, _86_, 67-79.

Smoke, W. H., & Zajonc, R. B. (1962). On the reliability of group judgments and decisions. In J. H. Creswell, H. Solomon, and P. Suppes (Eds), _Mathematical methods in small group process_ (pp. 279-290). Stanford, CA: Stanford University Press.

Stasser, G. (1988). Computer simulation as a research tool: The DISCUSS model of group decision making. _Journal of Experimental Social_

Psychology, 24, 393-422.

Stasser, G., Kerr, N. L., & Davis J. H. (in press). Influence processes and consensus models in small groups. In P. B. Paulus (Ed.), Psychology of group influence. 2nd Ed. Hillsdale, N.J.: Earlbaum.

Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. Journal of Personality and Social Psychology, 48, 1467-1478.

Stasser, G., & Titus, W. (1987). Effects of information load and percentage of shared information on the dissemination of unshared information during group discussion. Journal of Personality and Social Psychology, 53, 81-93.

Steiner, I. D. (1966). Models for inferring relationships between group size and potential group productivity. Behavioral Science, 11, 273-283.

Steiner, I. D. (1972). Group process and productivity. New York: Academic Press.

Thomas, E. J., & Fink, C. F. (1961). Models of group problem solving. Journal of Abnormal and Social Psychology, 63, 53-63.

Tuckman, B. W. (1967). Group composition and group performance of structured and unstructured tasks. Journal of Experimental Social Psychology, 3, 25-40.

Tuckman, B. W., & Lorge, I. (1962). Individual ability as a determinant of group superiority. Human Relations, 15, 45-51.

Vinokur, A., & Burnstein, E. (1974). Effects of partially shared persuasive arguments on group-induced shifts: A group-problem-solving approach. Journal of Personality and Social Psychology, 29, 305-315.

Yetton, P. W., & Bottger, P. C. (1983). The relationships amongst group size, member ability, decision schemes and performance. Organizational Behavior and Human Performance, 32, 145-159.

Zajonc, R. B., Wolosin, R. J., Wolosin, M. A., & Sherman, S. J. (1968). Individual and group risk taking in a two-choice situation. Journal of Experimental Social Psychology, 4, 89-106.

Zaleska, M. (1976). Majority influence on group choices among bets. Journal of Personality and Social Psychology, 33, 8-17.

Zaleska, M. (1978). Some experimental results: Majority influence on group decisions. In H. Brandstätter, J. H. Davis, & H. Schuler (Eds.), Dynamics of group decisions (pp. 67-74). Beverly Hills, CA: Sage.

Footnotes

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[1]The 400 groups were from four experiments, two previously published (Laughlin, 1988; Laughlin & McGlynn, 1986) and two not previously published. In addition to social combination processes, these experiments assessed mutual influence between a four-person group and another yoked unit (an individual, four independent individuals, a two-person group, or another four-person group). The yoked four-person group and other unit exchanged both hypotheses and evidence (card plays) on each trial, exchanged hypotheses only, exchanged evidence only, or exchanged neither, in between-group designs. Separate 2 x k [where k = the number of possible group hypotheses for a given distribution, such as three (C, P_0, N_0) for C_4, four for C_3P_1, and so on] tests of the proportions of possible group hypotheses were conducted for each of the six pairwise comparisons of the four exchange conditions for each of the 38 distributions of member hypotheses. Since some distributions did not occur for some conditions, there were 189 2 x k tests. Of these 189, only 1 was significant at $p < .05$, $df = k-1$, indicating comparable social combination processes over the four exchange conditions. Accordingly, the exchange conditions are not further considered.

Table 1

A Theory of Collective Induction

Postulate 1: Group problem solving and decision making is a social combination process that maps a distribution of individual group member preferences onto a single collective group response.

Postulate 2: Group problem solving and decision making tasks may be ordered on a continuum anchored by intellective and judgmental tasks.

Postulate 3: A demonstrably correct group response requires four conditions:

Postulate 3a: There must be group consensus on a verbal or quantitative conceptual system.

Postulate 3b: There must be sufficient information for solution within the system.

Postulate 3c: The group members who are not themselves able to achieve the correct response must have sufficient knowledge of the system to recognize and accept a correct response if it is proposed by other group members.

Postulate 3d: The correct members must have sufficient ability, motivation, and time to demonstrate the correct response to the incorrect members.

Postulate 4: The number of group members that is necessary and sufficient for a group response is inversely proportional to the demonstrability of the response.

Postulate 5: If at least two members propose the same hypothesis the group selects among only those hypotheses proposed by the group members; if no two members propose the same hypothesis the group selects among the hypotheses proposed by the group members and proposes a new emergent group hypothesis with probability 1/S (where S is group size).

Postulate 6: If at least two members propose plausible and/or correct hypotheses the group selects among proposed plausible and/or correct hypotheses only; if one or no members propose a plausible or correct hypothesis the group selects among all proposed hypotheses.

Postulate 7: The distribution of group member hypotheses determines the group hypothesis:

Postulate 7a: If all group members propose the same hypothesis the group proposes that hypothesis.

Postulate 7b: If a majority of group members propose the same hypothesis the group follows a compromise between a majority process and a proportionality process.

Postulate 7c: If two or more subgroups of equal size (with at least two members per subgroup) each propose a different hypothesis the group follows a proportionality process.

Postulate 7d: If a plurality of group members propose the same hypothesis the group follows a compromise between a plurality process and a proportionality process.

Postulate 7e: If all group members propose a different hypothesis the group follows a proportionality process and proposes a new hypothesis with probability 1/S (where S = group size).

Table 2

Predicted Probabilities of Group Hypotheses from Seven Postulates

	Type of Group Hypothesis										
Distribution	C	P_4	P_3	P_2	P_1	P_0	N_4	N_3	N_2	N_1	N_0
C_4	1.000	--	--	--	--	.000	--	--	--	--	.000
C_3P_1	.875	--	--	--	.125	.000	--	--	--	--	.000
C_3N_1	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_2P_2	.500	--	--	.500	--	.000	--	--	--	--	.000
$C_2P_1P_1$	.750	--	--	--	.250	.000	--	--	--	--	.000
$C_2P_1N_1$	.833	--	--	--	.167	.000	--	--	--	.000	.000
C_2N_2	1.000	--	--	--	--	.000	--	--	.000	--	.000
$C_2N_1N_1$	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_1P_3	.125	--	.875	--	--	.000	--	--	--	--	.000
$C_1P_2P_1$	.125	--	--	.750	.125	.000	--	--	--	--	.000
$C_1P_2N_1$	.167	--	--	.833	--	.000	--	--	--	.000	.000
$C_1P_1P_1P_1$	.188	--	--	--	.563	.250	--	--	--	--	.000
$C_1P_1P_1N_1$	.250	--	--	--	.500	.250	--	--	--	.000	.000
$C_1P_1N_2$	.500	--	--	--	.500	.000	--	--	.000	--	.000
$C_1P_1N_1N_1$	.375	--	--	--	.375	.250	--	--	--	.000	.000
C_1N_3	.125	--	--	--	--	.000	--	.875	--	--	.000
$C_1N_2N_1$	.125	--	--	--	--	.000	--	--	.750	.125	.000
$C_1N_1N_1N_1$	.188	--	--	--	--	.250	--	--	--	.563	.000

(CONT.)

P_4	.00	1.000	--	--	--	.000	--	--	--	--	.000
P_3P_1	.000	--	.875	--	.125	.000	--	--	--	--	.000
P_3N_1	.000	--	1.000	--	--	.000	--	--	--	.000	.000
P_2P_2	.000	--	--	1.000	--	.000	--	--	--	--	.000
$P_2P_1P_1$	.000	--	--	.750	.250	.000	--	--	--	--	.000
$P_2P_1N_1$	.000	--	--	.833	.167	.000	--	--	--	.000	.000
P_2N_2	.000	--	--	1.000	--	.000	--	--	.000	--	.000
$P_2N_1N_1$	.000	--	--	1.000	--	.000	--	--	--	.000	.000
$P_1P_1P_1P_1$	.000	--	--	--	.750	.250	--	--	--	--	.000
$P_1P_1P_1N_1$	.000	--	--	--	.750	.250	--	--	--	.000	.000
$P_1P_1N_2$	.000	--	--	--	1.000	.000	--	--	.000	--	.000
$P_1P_1N_1N_1$	.000	--	--	--	.750	.250	--	--	--	.000	.000
P_1N_3	.000	--	--	--	.125	.000	--	.875	--	--	.000
$P_1N_2N_1$	.000	--	--	--	.125	.000	--	--	.750	.125	.000
$P_1N_1N_1N_1$	.000	--	--	--	.188	.250	--	--	--	.563	.000
N_4	.000	--	--	--	--	.00	1.000	--	--	--	.000
N_3N_1	.000	--	--	--	--	.000	--	.875	--	.125	.000
N_2N_2	.000	--	--	--	--	.000	--	--	1.000	--	.000
$N_2N_1N_1$	.000	--	--	--	--	.000	--	--	.750	.250	.000
$N_1N_1N_1N_1$	.000	--	--	--	--	.000	--	--	--	.750	.250

Note. C = correct hypothesis, P = plausible hypothesis, N = nonplausible hypothesis. Subscripts indicate the number of group members who propose a given hypothesis. Dashes (--) indicate impossible group responses for a given distribution.

Table 3

Predicted Probabilities of Group Hypotheses from Proportionality Social Combination Process Among Correct and Plausible Hypotheses

	Type of Group Hypothesis										
Distribution	C	P_4	P_3	P_2	P_1	P_0	N_4	N_3	N_2	N_1	N_0
C_4	1.000	--	--	--	--	.000	--	--	--	--	.000
C_3P_1	.750	--	--	--	.250	.000	--	--	--	--	.000
C_3N_1	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_2P_2	.500	--	--	.500	--	.000	--	--	--	--	.000
$C_2P_1P_1$	.500	--	--	--	.500	.000	--	--	--	--	.000
$C_2P_1N_1$	.667	--	--	--	.333	.000	--	--	--	.000	.000
C_2N_2	1.000	--	--	--	--	.000	--	--	.000	--	.000
$C_2N_1N_1$	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_1P_3	.250	--	.750	--	--	.000	--	--	--	--	.000
$C_1P_2P_1$	.250	--	--	.500	.250	.000	--	--	--	--	.000
$C_1P_2N_1$	.333	--	--	.667	--	.000	--	--	--	.000	.000
$C_1P_1P_1P_1$	.250	--	--	--	.750	.000	--	--	--	--	.000
$C_1P_1P_1N_1$	.333	--	--	--	.667	.000	--	--	--	.000	.000
$C_1P_1N_2$	.500	--	--	--	.500	.000	--	--	.000	--	.000
$C_1P_1N_1N_1$	.500	--	--	--	.500	.000	--	--	--	.000	.000
C_1N_3	1.000	--	--	--	--	.000	--	.000	--	--	.000
$C_1N_2N_1$	1.000	--	--	--	--	.000	--	--	.000	.000	.000
$C_1N_1N_1N_1$	1.000	--	--	--	--	.000	--	--	--	.000	.000

(CONT.)

P_4	.00	1.000	--	--	--	.000	--	--	--	--	.000
P_3P_1	.000	--	.750	--	.250	.000	--	--	--	--	.000
P_3N_1	.000	--	1.000	--	--	.000	--	--	--	.000	.000
P_2P_2	.000	--	--	1.000	--	.000	--	--	--	--	.000
$P_2P_1P_1$	.000	--	--	.500	.500	.000	--	--	--	--	.000
$P_2P_1N_1$	.000	--	--	.667	.333	.000	--	--	--	.000	.000
P_2N_2	.000	--	--	1.000	--	.000	--	--	.000	--	.000
$P_2N_1N_1$	.000	--	--	1.000	--	.000	--	--	--	.000	.000
$P_1P_1P_1P_1$	.000	--	--	--	1.000	.000	--	--	--	--	.000
$P_1P_1P_1N_1$	.000	--	--	--	1.000	.000	--	--	--	.000	.000
$P_1P_1N_2$	.000	--	--	--	1.000	.000	--	--	.000	--	.000
$P_1P_1N_1N_1$	.000	--	--	--	1.000	.000	--	--	--	.000	.000
P_1N_3	.000	--	--	--	1.000	.000	--	.000	--	--	.000
$P_1N_2N_1$	.000	--	--	--	1.000	.000	--	--	.000	.000	.000
$P_1N_1N_1N_1$	.000	--	--	--	1.000	.000	--	--	--	.000	.000
N_4	.000	--	--	--	--	.00	1.000	--	--	--	.000
N_3N_1	.000	--	--	--	--	.000	--	.750	--	.250	.000
N_2N_2	.000	--	--	--	--	.000	--	--	1.000	--	.000
$N_2N_1N_1$	.000	--	--	--	--	.000	--	--	.500	.500	.000
$N_1N_1N_1N_1$	.000	--	--	--	--	.000	--	--	--	1.000	.000

Note. C = correct hypothesis, P = plausible hypothesis, N = nonplausible hypothesis. Subscripts indicate the number of group members who propose a given hypothesis. Dashes (--) indicate impossible group responses for a given distribution.

Table 4

Predicted Probabilities of Group Hypotheses from Majorty, Plurality Otherwise, Proportionality Otherwise, Social Combination Process among All Proposed Hypotheses

Distribution	Type of Group Hypothesis										
	C	P_4	P_3	P_2	P_1	P_0	N_4	N_3	N_2	N_1	N_0
C_4	1.000	--	--	--	--	.000	--	--	--	--	.000
C_3P_1	1.000	--	--	--	.000	.000	--	--	--	--	.000
C_3N_1	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_2P_2	.500	--	--	.500	--	.000	--	--	--	--	.000
$C_2P_1P_1$	1.000	--	--	--	.000	.000	--	--	--	--	.000
$C_2P_1N_1$	1.000	--	--	--	.000	.000	--	--	--	.000	.000
C_2N_2	.500	--	--	--	--	.000	--	--	.500	--	.000
$C_2N_1N_1$	1.000	--	--	--	--	.000	--	--	--	.000	.000
C_1P_3	.000	--	1.000	--	--	.000	--	--	--	--	.000
$C_1P_2P_1$	.000	--	--	1.000	.000	.000	--	--	--	--	.000
$C_1P_2N_1$	.000	--	--	1.000	--	.000	--	--	--	.000	.000
$C_1P_1P_1P_1$	.250	--	--	--	.750	.000	--	--	--	--	.000
$C_1P_1P_1N_1$	.250	--	--	--	.500	.000	--	--	--	.250	.000
$C_1P_1N_2$	.000	--	--	--	.000	.000	--	--	1.000	--	.000
$C_1P_1N_1N_1$	.250	--	--	--	.250	.000	--	--	--	.500	.000
C_1N_3	.000	--	--	--	--	.000	--	1.000	--	--	.000
$C_1N_2N_1$	.000	--	--	--	--	.000	--	--	1.000	.000	.000
$C_1N_1N_1N_1$	.250	--	--	--	--	.000	--	--	--	.750	.000

(CONT.)

P_4	.00	1.000	--	--	--	.000	--	--	--	--	.000
P_3P_1	.000	--	1.000	--	.000	.000	--	--	--	--	.000
P_3N_1	.000	--	1.000	--	--	.000	--	--	--	.000	.000
P_2P_2	.000	--	--	1.000	--	.000	--	--	--	--	.000
$P_2P_1P_1$	.000	--	--	1.000	.000	.000	--	--	--	--	.000
$P_2P_1N_1$	.000	--	--	1.000	.000	.000	--	--	--	.000	.000
P_2N_2	.000	--	--	.500	--	.000	--	--	.500	--	.000
$P_2N_1N_1$	.000	--	--	1.000	--	.000	--	--	--	.000	.000
$P_1P_1P_1P_1$	.000	--	--	--	1.000	.000	--	--	--	--	.000
$P_1P_1P_1N_1$	.000	--	--	--	.750	.000	--	--	--	.250	.000
$P_1P_1N_2$	.000	--	--	--	.000	.000	--	--	1.000	--	.000
$P_1P_1N_1N_1$	.000	--	--	--	.500	.000	--	--	--	.500	.000
P_1N_3	.000	--	--	--	.000	.000	--	1.000	--	--	.000
$P_1N_2N_1$	.000	--	--	--	.000	.000	--	--	1.000	.000	.000
$P_1N_1N_1N_1$	.000	--	--	--	.250	.000	--	--	--	.750	.000
N_4	.000	--	--	--	--	.00	1.000	--	--	--	.000
N_3N_1	.000	--	--	--	--	.000	--	1.000	--	.000	.000
N_2N_2	.000	--	--	--	--	.000	--	--	1.000	--	.000
$N_2N_1N_1$	.000	--	--	--	--	.000	--	--	1.000	.000	.000
$N_1N_1N_1N_1$	.000	--	--	--	--	.000	--	--	--	1.000	.000

Note. C = correct hypothesis, P = plausible hypothesis, N = nonplausible hypothesis. Subscripts indicate the number of group members who propose a given hypothesis. Dashes (--) indicate impossible group responses for a given distribution.

Table 5

Observed Probabilities of Group Hypotheses for 400 Groups

	Type of Group Hypothesis											
Distribution	C	P_4	P_3	P_2	P_1	P_0	N_4	N_3	N_2	N_1	N_0	Sum
C_4	1.000	--	--	--	--	.000	--	--	--	--	.000	673
C_3P_1	.887	--	--	--	.085	.028	--	--	--	--	.000	106
C_3N_1	.909	--	--	--	--	.023	--	--	--	.068	.000	44
C_2P_2	.593	--	--	.370	--	.000	--	--	--	--	.037	27
$C_2P_1P_1$	.792	--	--	--	.132	.057	--	--	--	--	.019	53
$C_2P_1N_1$	.762	--	--	--	.143	.048	--	--	--	.000	.048	21
C_2N_2	.000	--	--	--	--	.000	--	--	.000	--	.000	0
$C_2N_1N_1$	.667	--	--	--	--	.000	--	--	--	.333	.000	6
C_1P_3	.200	--	.767	--	--	.033	--	--	--	--	.000	30
$C_1P_2P_1$	.206	--	--	.618	.088	.088	--	--	--	--	.000	34
$C_1P_2N_1$	.333	--	--	.667	--	.000	--	--	--	.000	.000	15
$C_1P_1P_1P_1$	.389	--	--	--	.333	.259	--	--	--	--	.019	54
$C_1P_1P_1N_1$	.481	--	--	--	.222	.259	--	--	--	.037	.000	27
$C_1P_1N_2$	.000	--	--	--	.000	.000	--	--	.500	--	.500	2
$C_1P_1N_1N_1$	.400	--	--	--	.333	.200	--	--	--	.000	.067	15
C_1N_3	.000	--	--	--	--	.000	--	1.000	--	--	.000	1
$C_1N_2N_1$	.000	--	--	--	--	.000	--	--	1.000	.000	.000	2
$C_1N_1N_1N_1$	.750	--	--	--	--	.000	--	--	--	.250	.000	4

(CONT.)

P_4	.004	.986	--	--	--	.010	--	--	--	--	.000	913
P_3P_1	.000	--	.899	--	.073	.022	--	--	--	--	.005	698
P_3N_1	.012	--	.893	--	--	.030	--	--	--	.041	.024	169
P_2P_2	.000	--	--	.949	--	.051	--	--	--	--	.000	198
$P_2P_1P_1$	.002	--	--	.622	.278	.093	--	--	--	--	.006	540
$P_2P_1N_1$	.005	--	--	.633	.173	.097	--	--	--	.056	.036	196
P_2N_2	.000	--	--	.571	--	.036	--	--	.393	--	.000	28
$P_2N_1N_1$	.000	--	--	.744	--	.077	--	--	--	.051	.128	39
$P_1P_1P_1P_1$	.010	--	--	--	.719	.261	--	--	--	--	.010	310
$P_1P_1P_1N_1$	.004	--	--	--	.642	.248	--	--	--	.035	.071	226
$P_1P_1N_2$	.000	--	--	--	.455	.121	--	--	.364	--	.061	33
$P_1P_1N_1N_1$	.008	--	--	--	.447	.220	--	--	--	.228	.098	123
P_1N_3	.000	--	--	--	.032	.065	--	.903	--	--	.000	31
$P_1N_2N_1$	.000	--	--	--	.216	.081	--	--	.459	.108	.135	37
$P_1N_1N_1N_1$	.016	--	--	--	.371	.210	--	--	--	.290	.113	62
N_4	.022	--	--	--	--	.000	.978	--	--	--	.000	45
N_3N_1	.000	--	--	--	--	.000	--	.938	--	.063	.000	16
N_2N_2	.000	--	--	--	--	.000	--	--	1.000	--	.000	2
$N_2N_1N_1$	.000	--	--	--	--	.000	--	--	.824	.176	.000	17
$N_1N_1N_1N_1$	.000	--	--	--	--	.125	--	--	--	.625	.250	24
Sum	959	900	804	734	753	341	44	44	59	104	79	4821

Note. C = correct hypothesis, P = plausible hypothesis, N = nonplausible hypothesis. Subscripts indicate the number of group members who propose a given hypothesis. Dashes (--) indicate impossible group responses for a given distribution.

Table 6

Sums of Squared Predicted Minus Obtained Proportions

Distribution	Postulates (Table 2)	Proportionality (Table 3)	Majority (Table 4)	Frequency
C_4	.00000000	.00000000	.00000000	673
C_3P_1	.00000109	.00002232	.00001022	106
C_3N_1	.00000104	.00000104	.00000104	44
C_2P_2	.00000078	.00000078	.00000078	27
$C_2P_1P_1$	.00000209	.00002664	.00000794	53
$C_2P_1N_1$	.00000018	.00000105	.00000165	21
C_2N_2	.00000000	.00000000	.00000000	0
$C_2N_1N_1$	.00000032	.00000032	.00000032	6
C_1P_3	.00000056	.00000021	.00000344	30
$C_1P_2P_1$	.00000162	.00000270	.00001026	34
$C_1P_2N_1$	.00000050	.00000000	.00000200	15
$C_1P_1P_1P_1$	.00001210	.00003310	.00003310	54
$C_1P_1P_1N_1$	.00000430	.00000918	.00000794	27
$C_1P_1N_2$	.00000016	.00000016	.00000008	2
$C_1P_1N_1N_1$	.00000012	.00000092	.00000316	15
C_1N_3	.00000000	.00000008	.00000000	1
$C_1N_2N_1$	.00000003	.00000032	.00000000	2
$C_1N_1N_1N_1$	.00000029	.00000008	.00000032	4

(CONT.)

P_4	.00001190	.00001190	.00001190	913
P_3P_1	.00009710	.00118870	.00031266	698
P_3N_1	.00001849	.00001849	.00001849	169
P_2P_2	.00000882	.00000882	.00000882	198
$P_2P_1P_1$	.00032266	.00091626	.00286506	540
$P_2P_1N_1$	.00009012	.00006571	.00029820	196
P_2N_2	.00001158	.00001158	.00000056	28
$P_2N_1N_1$	.00000593	.00000593	.00000593	39
$P_1P_1P_1P_1$	.00000482	.00060696	.00060696	310
$P_1P_1P_1N_1$	.00003984	.00043062	.00027150	226
$P_1P_1N_2$	.00002074	.00002074	.00002890	33
$P_1P_1N_1N_1$	.00009986	.00027010	.00008861	123
P_1N_3	.00000056	.00007224	.00000056	31
$P_1N_2N_1$	.00000718	.00005025	.00002253	37
$P_1N_1N_1N_1$	.00002055	.00008884	.00004695	62
N_4	.00000008	.00000008	.00000008	45
N_3N_1	.00000008	.00000072	.00000008	16
N_2N_2	.00000000	.00000000	.00000000	2
$N_2N_1N_1$	.00000018	.00000265	.00000072	17
$N_1N_1N_1N_1$	.00000072	.00000541	.00000541	24
Sum:	.00078639	.00387490	.00467617	4821
Square Root of Sum:	.0280	.0622	.0684	

Table 7

Proportions of Confirming and Disconfirming Card Selections for Five Types of Group Hypotheses

Type of Group Hypothesis	Confirming	Disconfirming	Overall
Type 1	.775	.225	.064
Type 2	.661	.339	.690
Type 3	.800	.200	.005
Type 4	.618	.382	.069
Type 5	.891	.109	.172
Overall	.706	.294	

Note: Type 1: the proposed hypothesis is plausible but less general than the correct rule (e.g., the hypothesis "diamonds and spades alternate" for the correct rule "red and black alternate"); Type 2: the proposed hypothesis is plausible but based on a different set of relationships than the correct rule (e.g., the hypothesis "even numbers" for the correct rule "red and black alternate"); Type 3: the proposed hypothesis is plausible but more general than the correct rule (e.g., the hypothesis "red and black alternate" for the correct rule "diamonds and spades alternate"); Type 4: the proposed hypothesis is nonplausible (e.g., the hypothesis "diamonds" when a diamond has been a nonexample or a spade has been an example of the correct rule "diamonds and spades alternate"); Type 5: the proposed hypothesis is the single correct rule.

Table 8

Probability of Correct, Plausible, and Nonplausible Group Hypotheses on Trial t+1 Conditioned on Five Types of Confirming and Disconfirming Card Selections on Trial t

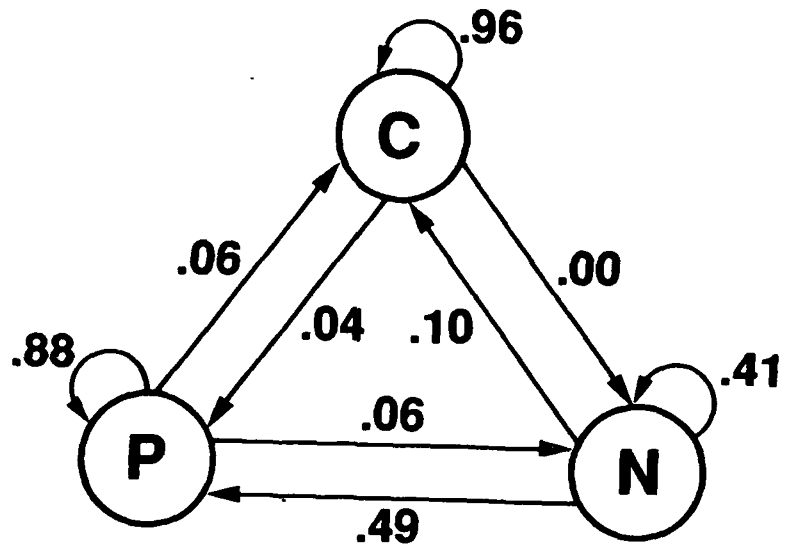
		Group Hypothesis on t+1			
Type	Selection on t	Correct	Plausible	Nonplausible	Sum
1	Confirming	.104	.891	.005	221
	Disconfirming	.422	.578	.000	64
2	Confirming	.055	.874	.071	2018
	Disconfirming	.038	.913	.049	1033
3	Confirming	.313	.688	.000	16
	Disconfirming	.250	.500	.250	4
4	Confirming	.080	.564	.356	188
	Disconfirming	.069	.414	.517	116
5	Confirming	.962	.037	.001	678
	Disconfirming	.928	.060	.012	83
Sum		957	3138	326	4421

Figure Captions

Figure 1. Illustration for correct rule "two red and one black alternate."

Figure 2. Transition probabilities from correct, plausible, or nonplausible group hypotheses on trial *t* to correct, plausible, or nonplausible group hypotheses on trial *t*+1.

8 D	8 H	10 S	K D	7 H	7 C	K H
	8 H		A C			J S
			K C			


.96
C
.06
.00
.04
.10
.88
.41
.06
P
N
.49